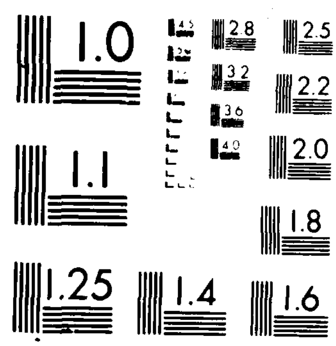
AD-A170 150 MICROSCALE DEFECT KINETICS IN MELT-GROWN GAAS(U) 1/1
MASSACHUSETTS INST OF TECH CAMBRIDGE DEPT OF MATERIALS
SCIENCE AND ENGINEERING H C GATOS ET AL. 31 AUG 86

UNCLASSIFIED N00014-83-K-0501 F/G 20/12 NL



ROCOPY RESOLUTION TEST CHART

(12)

TO: OFFICE OF NAVAL RESEARCH
ARLINGTON, VIRGINIA 22219

Final Technical Report

For Period

1 August 1983 to 31 August 1986

on

MICROSCALE DEFECT KINETICS IN MELT-GROWN GaAs

Contract N0014-83-K-0581

Submitted by

Professor Harry C. Gatos
and
Dr. Jacek Lagowski
Department of Materials Science and Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

I. SUMMARY OF WORK ACCOMPLISHED

Our research on the kinetics of defects in melt-grown GaAs involved crystal growth experiments and post-growth treatments of crystals combined with extensive characterization of electronic properties related to defects.

In our crystal growth experiments we used an especially constructed Czochralski-type puller equipped with a vertical magnetic field for the growth of GaAs under conditions of suppressed convection. We have identified for the first time a beneficial effect of the magnetic field on the compensation ratio and electron mobility (Ref. 1).

Experiments on doping with oxygen ~~isotope ^{18}O~~ of GaAs crystals grown by the Horizontal Bridgman technique have revealed an anomalous silicon segregation behavior governed by chemical reactions in a closed growth ampul rather than standard impurity distribution during the solidification (Refs. 2 and 3).

Experiments on fast growth of GaAs by the LEC technique using pulling rates of up to 2 inch/h showed a significant decrease of EL2 concentration with increasing the pulling rate. We have shown that this effect originates from fast cooling of the crystal grown under high pulling rates (Ref. 4).

We have essentially completed a detailed study on the effects of plastic deformation on deep levels in GaAs (Refs. 5,6). This study combined electrical and optical characterization of crystals subjected to plastic deformation at 400°C.

They showed, contrary to present belief, that no midgap levels were introduced in GaAs by plastic deformation. However, the deformation did introduce acceptor states at about 0.45 eV above the valence band, which caused an effective free carrier removal in n-type GaAs.

GaAs Growth in a Magnetic Field

A series of GaAs crystals were grown in our laboratory using the LEC apparatus with a magnetic field parallel to the crystal growth axis. As shown in Fig. 1, the portion of the crystal grown without a magnetic field exhibits pronounced striations revealed by "depth profiling" of differentially etched crystals and by cathodoluminescence scanning. The magnitude of inhomogeneities decreased with increasing magnetic field.

The effect of a magnetic field on the macroscopic properties of LEC GaAs are summarized in Table I, and they are also presented in Fig. 2. It is evident that portions of GaAs grown in a magnetic field of 3500 Oe have higher mobility values and lower compensation ratios than those grown without a magnetic field.

The results of a magnetic field on GaAs properties established in the course of this study will be discussed extensively in a Ph.D. thesis (Ref. 1) currently under preparation.

Incorporation of Oxygen and Silicon during HB Growth of GaAs

Oxygen has profound effects on the key electronic properties and point defects of GaAs crystals. Thus, when added in the growth system, it decreases the free electron concentration and enhances the concentration of deep donors in the resulting crystals (Ref. 2). We have studied the incorporation of oxygen in GaAs grown by the Horizontal Bridgman method employing oxygen isotope ^{18}O. With this approach we have decreased the detection limit by secondary ion mass spectrometry (SIMS) to as low as 4×10^{13} oxygen atoms/cm^3.

Consequently, we [illegible] that the concentration of oxygen in intentionally doped crystals was [illegible] cm^3, and it decreased from the seed end to the tail [illegible] concentration and the [illegible].

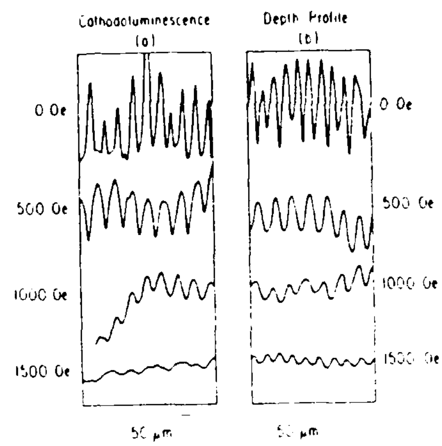

Cathodoluminescence
(a)
Depth Profile
(b)
0 Oe
500 Oe
1000 Oe
1500 Oe
0 Oe
500 Oe
1000 Oe
50 μm

Figure 1.

TABLE I

Effect of Magnetic Field on Properties of LEC-GaAs

Magnetic Field (Oe)	Electron Mobility (cm^2/Vs)	Electron Concentration (cm^{-3})	Compensation Ratio
3500	3600	2.49E16	.76
0	3760	1.69E16	.78
3500	4030	2.37E16	.68
0	3735	2.07E16	.75
3500	4000	3.22E16	.62
0	3160	3.60E16	.76

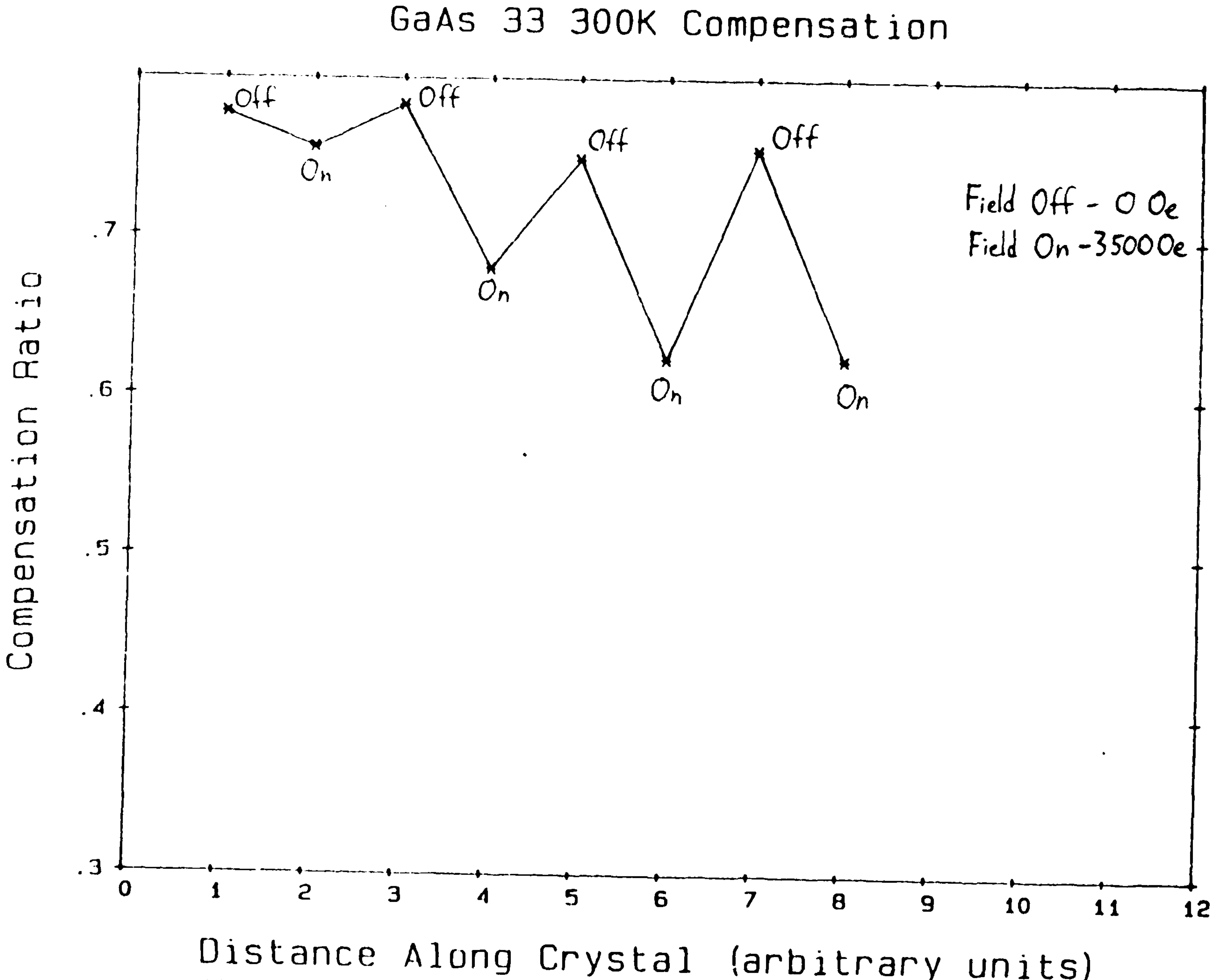

GaAs 33 300K Compensation
Off
On
Off
On
Off
On
Off
On
Field Off - 0 Oe
Field On -3500Oe
.7
.6
.5
.4
.3
0
1
2
3
4
5
6
7
8
9
10
11
12
Compensation Ratio
Distance Along Crystal (arbitrary units)

Fig. 2.

These results showed that oxygen and silicon incorporation during GaAs growth is controlled by the chemical eqilibrium rather than by standard impurity distribution during solidification. The results outlined above are currently being prepared for publication (Ref. 3).

Deformation-Induced Defects in GaAs

We have completed a detailed study of the effects of plastic deformation on electrical and optical propetties of GaAs. Employing DLTS we have found no appreciable increase in the concentration of the main deep donor EL2 (see Fig. 3). However, we have also found (using optical DLTS) deformation-introduced hole traps of an activation energy $E_v + 0.45$ eV (see Fig. 4). These hole traps act as acceptor levels and they are responsible for the removal of free electrons upon plastic deformation. Detailed results of this study will be presented in a forthcoming publication (Ref. 6).

II. INDEX OF REFERENCES

1. L.M. Pawlowicz, "Evolution of Defects in LEC-GaAs," Ph.D. Thesis, MIT, 1987, under preparation.

2. H.C. Gatos, M. Skowronski, L. Pawlowicz and J. Lagowski, "Oxygen in GaAs: Direct and Indirect Effects," Inst. Phys. Conf. Ser. 74, 41 (1985).

3. J. Lagowski, D.G. Lin and H.C. Gatos, "Incorporation of Oxygen and Silicon into GaAs during Horizontal Bridgman Growth," in preparation for publication.

4. J. Lagowski, and H.C. Gatos, "Cooling versus Solidification, Key Issue in Melt-Grown GaAs Crystals," presented at 1st Conf. of American Assoc. Crystal Growth East, Atlantic City, October 1986.

5. H.C. Gatos and J.Lagowski, "EL2 and Related Defects in GaAs--Challenges and Pitfalls," Materials Research Soc. Symp. Proc. 46, 153 (1985).

6. M. Skowronski, J. Lagowski and H.C. Gatos, "Deformation Induced Defects in GaAs," in preparation for publication.

7. M. Skowronski, D.G. Lin, J. Lagowski, L.M. Pawlowicz, K.Y. Ko and H.C. Gatos, "High Resolution Optical Study of the Antisite Defect in GaAs: Correlation with EL2," Materials Research Soc. Symp. Proc. 46, [illegible] (1985).

8. W. Walukiewicz, Le Wang, L. Pawlowicz, J. Lagowski and H.C. Gatos, "Effect of Deep Level Ionization on Low Temperature Electron Mobility in SI GaAs," Semi-Insulating III-V Materials, Kah-nee-ta 1984, edited by D.C. Look and J.S. Blakemore, Shiva Publishing, Ltd., Nantwich, England, 1984.

III. INDEX OF REPORTS

1. Publications/Patents/Presentations/Honors Report - 1 October 1983 through 30 September 1984.

2. Annual Progress Report for Period 1 August 1984 to 31 July 1985

3. Publications/Patents/Oresentations/Honors Report - 1 October 1984 through 30 September 1985

4. Final Technical Report for Period 1 August 1983 to 31 August 1986

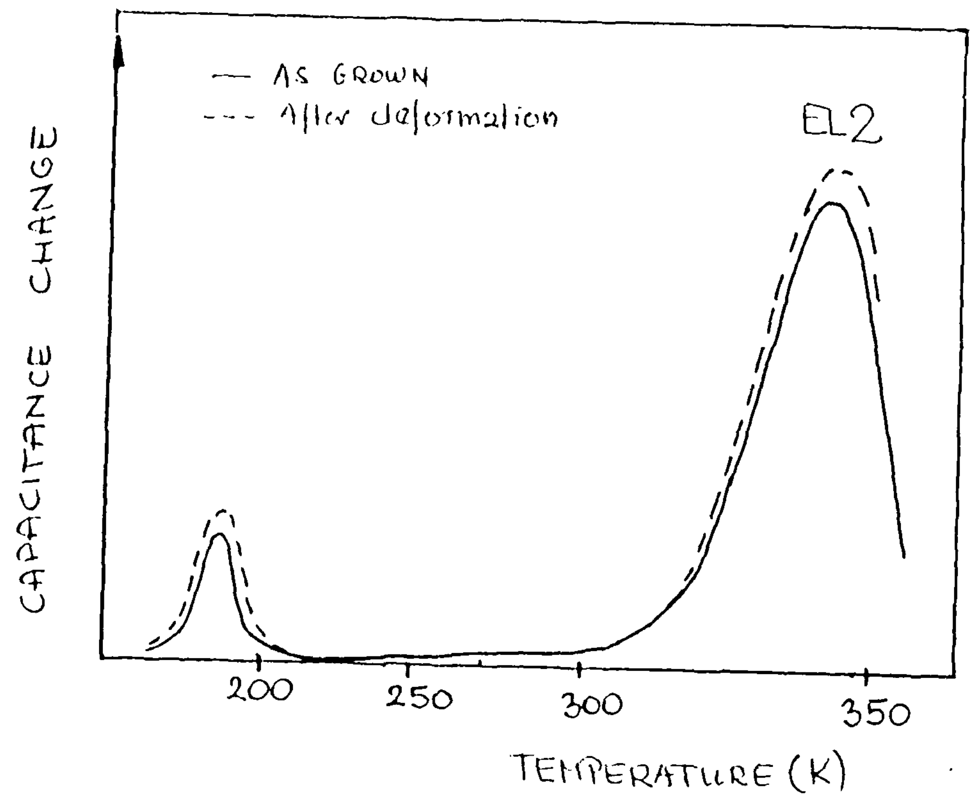
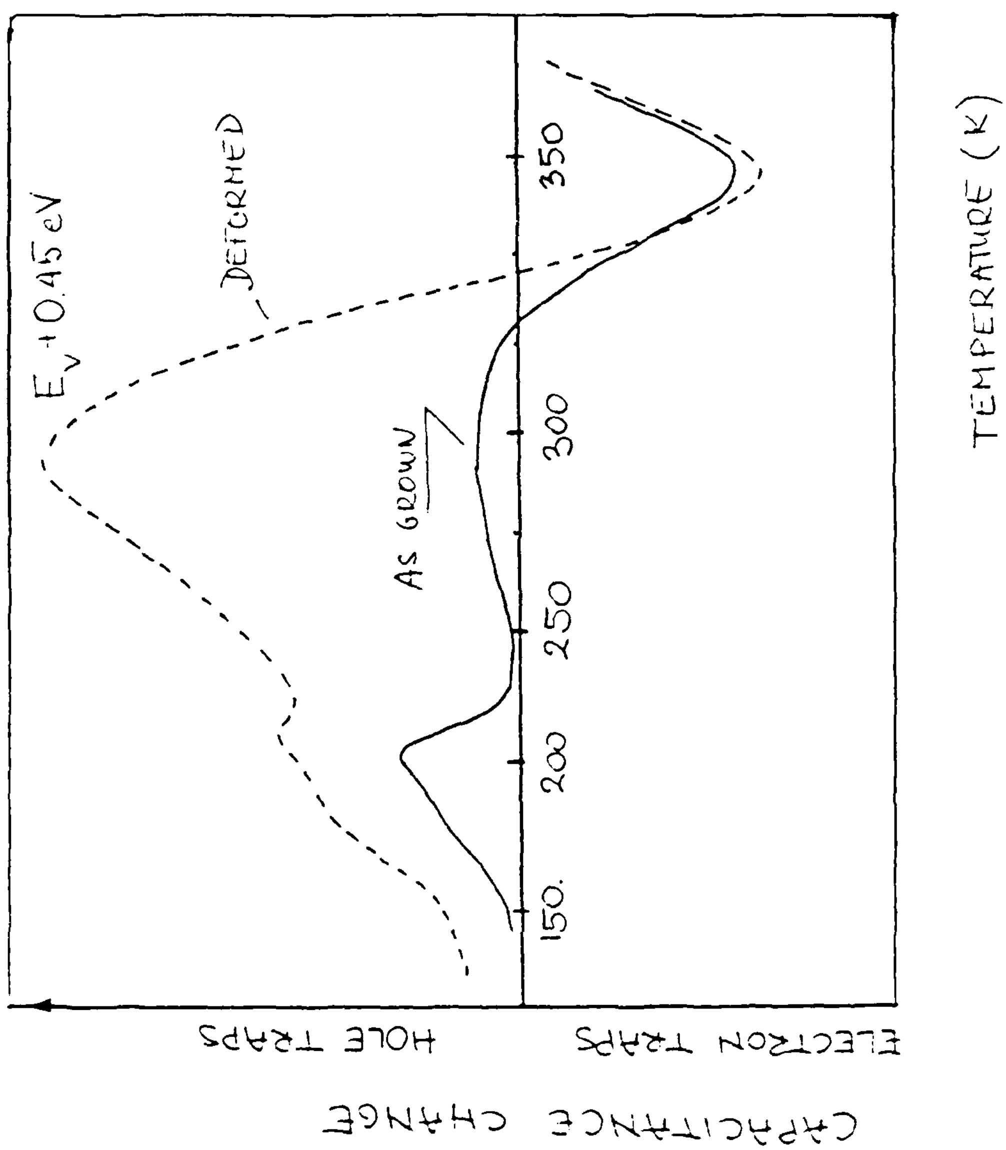

— AS GROWN
--- After deformation
EL2
CAPACITANCE CHANGE
200
250
300
350
TEMPERATURE (K)

Figure 3.



$E_v + 0.45$ eV
DEFORMED
AS GROWN
150
200
250
300
350
TEMPERATURE (K)
HOLE TRAPS
ELECTRON TRAPS
CAPACITANCE CHANGE

Figure 4.

END

4-87

DTIC